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UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
WASHINGTON, D. C.

SOIL AND WATER CONSERVATION INSTRUMENTS

No. 1 - Notes on the operation of the Fergusson recording
rain and snow gage

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Note: A supply of new weights for Fergusson recording mechanism can be obtained from the Hydrologic Division, Soil Conservation Service, Washington, D. C. Indicate the number of Fergusson gages to be corrected.

UNITED STATES DEPARTMENT OF AGRICULTURE
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H. H. Bennett, Chief

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INSTRUMENTS

No. 1 - Notes on the operation of the Fergusson recording
rain and snow gage :

by

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No. 1
NOTES ON THE OPERATION OF THE FERGUSSON
RECORDING RAIN AND SNOW GAGE*

INTRODUCTION

The Soil Conservation Service has purchased and now has in operation a considerable number of Fergusson type, recording rain and snow gages. Questions have arisen from time to time about details of their operation, particularly at times when there has appeared to be something wrong. This is written, therefore, with a possible over-emphasis on the wrong or weak points in the instruments. This should be understandable. For the history of the device and descriptions of the older types refer to Monthly Weather Review, July 1921, 49:379-384 and to Measurement of Precipitation, U. S. no. 771.

No attempt will be made to give the proper location of a gage relative to other gages, to the surrounding topography, or to nearby vegetation and objects. Nor will the effects of wind on the "catch" of the gage, as influenced by its height and shape, be discussed. These things are very important but because of our limited knowledge of them they are not discussed in these notes.

*These notes are the first of a series making up a manual of instrumentation for soil and water conservation research.

The diameter of the collecting ring is 8 inches, providing a catchment area of 0.349 square feet. A depth of 1 inch over this area makes a volume of 0.02908 cubic feet. The apparent weight of this volume of water, under usual weighing conditions, is about 821 grams.

The collecting bucket rests on a weighing platform and frame, which in turn are suspended from a spring. Precipitation caught in the bucket increases the load on the spring, causing it to deflect with a resultant lowering of the platform and frame. This deflection is proportional to the amount of the precipitation that has been collected. The movement of the frame is transmitted through a system of links and levers to the pen which marks a suitably graduated revolving chart. The ratio of the frame movement to the pen movement is controlled by the positions of the pinions relative to the pen arm system pivot. (See fig. 1.) Shortening the distances m and n increases the movement of the pen for a given frame movement or spring deflection.

OPERATION OF THE REVERSAL MECHANISM

Some of the Fergusson gages have failed to give a true record of rainfall. This has been particularly true of the '36 series of gages. The words and phrases that have been used describing the action of the gage and the type of record on the chart are: "sluggish", "hesitant", "jerky", "stair-step record", "reversal considerably below the three-inch line", etc. There probably has been more trouble of this nature than has been thought or observed, because it is usually not

discovered until a storm occurs which exceeds 3 inches of rainfall.

The reason for the failure of these gages to record the rainfall correctly has been, for the most part, a lack of sufficient driving force in the reversal mechanism to overcome the friction in the mechanism and that between the pen and chart. Instances of faulty record have no doubt also occurred because of binding between some part of the moving portion of the weighing mechanism and a stationary fixture such as the dash pot, but troubles of this kind are relatively easy to detect and correct, and therefore probably occur infrequently.

A symbolic diagram (fig. 1) has been prepared to help in the description of the mechanics of the operation of the gage, and in particular the reversal mechanism. Note that the pen arm is pivoted in a fixed position relative to the chart drum, and counterweighted so that for the first traverse of the pen across the chart (0-3 inches of precipitation) the right pinion rests at the bottom of the slot in the right link. For the second traverse (3-6 inches of precipitation) the pen moves downward due to the fact that the left pinion contacts the upper end of the bottom slot of the left link, the weight of the left link being more than enough to overcome the clockwise moment of the pen arm system plus friction. During the third traverse of the chart (6-9 inches of precipitation), the right pinion is in contact with the upper end of the slot in the right link, raising the left link with increasing amounts of precipitation.

The principal difficult, with some of the gages has been an insufficient resultant clockwise moment in the pen arm system to overcome the friction existent in the (0-3)-inch precipitation range; and the obvious means for correcting the difficulty is to increase the size of the pen arm counterweight. The less obvious and more uncertain way would be to decrease the friction in the system.

The friction between the pen and chart could probably be reduced by decreasing the tilt of the pen arm, but it may be that the amount of tilt employed is the minimum consistent with the attainment of positive contact between pen and chart; furthermore, this would be a difficult change to make. Oil could be put on the pinions and links, but this would be of temporary value and in the end worse than none at all because of gumminess resulting from evaporation, low temperature, and the collection of dust.

The probable reason for there being too small a counterweight on some of the gages is that the larger this weight, the less accurate is the recording of the total precipitation if the gage is working properly. But since the primary purpose of a recording rain gage is to make a record from which rainfall rates can be obtained, it seems that a small sacrifice in the accuracy of the determination of total catch should be made for the sake of obtaining positive dependable action of the instrument. In fact, there need be no sacrifice in accuracy due to adding more weight because a small correction, that can be calculated, may be made to the recorded amounts.

In order to determine the correction refer to figure 1 and analyze the forces acting. Thus the load on the weighing mechanism of the gage due to the pen arm and linkage system (weight of right link excepted) is as follows:

Precipitation Range Inches	Actual Load	Load Causing* Error	Correction** Inches
0-3	$\frac{N-M}{n} + L$	0	0
3-6	$L - \frac{N-M}{m}$	$-(N-M) (\frac{1}{n} + \frac{1}{m})$	$\frac{(N-M) (1/n + 1/m)}{821}$
6-9	$\frac{N-M - mL}{n}$	$-L (1 + m/n)$	$\frac{L (1 + m/n)}{821}$

* If gage is zero-ed in 0-3 inch range.

** Gage zero-ed in 0-3 inch range; all quantities expressed in gram-centimeter units.

where:

N = clockwise moment of the pen arm system

M = counterclockwise moment of the pen arm system

L = weight of left link

m = distance from pivot to left pinion

n = distance from pivot to right pinion

Since n and m , the distances from the pivot to the right and left pinions, respectively, are approximately equal, the correction for the (3-6)-inch range may be written $\frac{2(N-M)}{821 n}$ and that for the (6-9)-inch range $\frac{2 L}{821}$. Or, if it is considered that the resultant moment of the pen arm system is due to a weight, R , acting at the right pinion, then

the correction for the (3-6)-inch range is $\frac{2}{821} R$, R and L expressed in grams. A flaw can be picked in this analysis of the correction to be added to the chart reading, since friction effects and the variable weight of the ink in the pen have been neglected. Ordinarily these things should prove to have a negligible effect on the value of the correction to be used.

The weight, L, of the left link should be at least $2R$, assuming m and n are equal, since one-half the weight is needed to counterbalance R and the other half to overcome the friction during the 3-6 inch traverse.

The minimum value of R or the resultant clockwise moment of the pen arm system to have, in order that a gage will always work satisfactorily, is not readily determinable because of the variable nature of friction. For two of the '36 series of gages that were studied, R averaged 2.6 grams and L averaged 5.9 grams. These gages did not always work satisfactorily. Trials in the laboratory indicated that the weight should be considerably greater but there was no known way of telling the minimum necessary value to insure positive action at all times.

A value of R of 12.3 grams has been rather arbitrarily selected as being sufficient. This is between four and five times the amount provided by the manufacturer, and according to the analysis would cause an error of 0.03 inch in the recording of precipitation over the (3-6)-inch range. If the weight, L, of the left link is increased to $2R$ or 24.6 grams the error in the (6-9)-inch range would be 0.06 inch.

Another factor to be considered, and one that makes it desirable to limit the magnitudes of the additional weights, is the action of the gage at the reversal points. The chart record at these points will be a straight horizontal line for the period required to collect an amount of precipitation equal to the difference in corrections for the adjacent traverses. If R and L are as suggested above, this amount is 0.03 inch at both reversal points, and the period covered by the straight line will vary with the rain intensity, being 18 minutes at 0.1 inch per hour, 1.8 minutes at 1.0 inch per hour, etc.

An easy method of making an approximate determination of R is as follows:

1. Tie a small piece of thread to make a loop and hang it over the left pinion.
2. Load the catch bucket with an equivalent of $1 \frac{1}{2}$ to 2 inches of precipitation.
3. Cut pieces of wire solder or similar material to hang from the bottom of the thread loop.
4. Find the piece that brings the pen arm system into balance. In doing this it may be found helpful to use another piece of thread, relatively long and having a loop at one end. Put the loop over the pen and pull the pen and pen arm away from contact with the chart and pen lifter device, respectively.
5. The value of R is the weight of the piece bringing the system into balance if m and n are equal.

To find the approximate weight of the left link, hang the thread loop over the right pinion, load the bucket to the equivalent of about $5\frac{1}{2}$ inches of precipitation, and determine the necessary weight on the loop to bring the system into balance. This weight added to the value for R should be equal to the weight of the left link. (The more accurate method is to remove the link and weigh it.)

The design of the pen arm counterweight is such that it can be moved over a considerable range relative to the pivot. On one of the '36 series of gages this distance, d, could be varied between 2.7 and 3.25 cm which could change the value of R from 1.6 to 4.0 grams. From the analysis of the operation of the reversal mechanism, which shows that the minimum weight of the left link is a function of R, it appears that this provision for adjustment of the position of the counterweight is an undesirable feature. Once fixed in the proper place, it should not be carelessly changed.

Having selected a value for R, the force exerted by the right pinion on the bottom of the slot in the right link (0-3 inches), of 12.3 grams, there remains the problem of determining the size of counterweight needed to produce this force. Since the distance, n, from the pivot to the right pinion has been measured to be about 1.2 cm, the desired resultant clockwise moment of the pen arm system to be used in overcoming friction in the (0-3)-inch range is nR or 14.8 gram centimeters. This moment plus that needed to overcome the existent counterclockwise moment of the remainder of the pen arm system must be produced by the counterweight. The average value needed to

balance the system has been determined on the '36 gages to be 13.8 gram centimeters; thus, the counterweight should be of a size and at a distance from the pivot such that dW is equal to 28.6 gram centimeters. Somewhat arbitrarily selecting a value of 2.6 cm. for d , fixes the weight, W , of the counterweight at 11 grams. This compares with 6 grams furnished by the manufacturer.

The weight of the left link on these gages is about 5.9 grams. If R is increased to 12.3 grams, L should be increased to 24.6 grams; therefore, 18.7 grams should be added to the left link. The manner of doing this is not important except that, if added to the bottom as probably will be done, care should be taken that the appendage does not strike the frame of the instrument or the floor when the weighing platform is depressed.

For the benefit of those who desire to change the counterweight and the weight of the left link on one or more of the '36 series of gages in accordance with the suggestion given, a plan (fig. 2) for new weights has been prepared and a detailed procedure given as follows:

1. Remove the screws, A and B, at the top of both links, noting that the washers are between the frame and the links.
2. Loosen the pivot screw, enabling the complete removal of the reversal mechanism and pen arm system.
3. Replace the counterweight with one weighing approximately 11 grams and having its center of gravity at about 2.6 cm. from the pivot.
4. Remove the left pinion screw and take the left link off.
5. Hold a hot soldering iron on the 1/2-inch diameter weight at the bottom of the link until the solder melts and the link drops off.

(Be careful not to bend the link or mar it with the jaws of pliers or other tool.)

6. Solder on the new weight shown in figure 2.
7. Wash all sliding and turning parts with carbon tetrachloride or other volatile cleaning fluid.
8. Replace the mechanism to its original position, making sure that the pivot is centered in the pivot screw. Enough end play will be provided by turning the pivot screw back a half turn from the snug position. If all of the work is carefully done and none of the other screws loosened, there should be no effect on the adjustment. The exact weights to use for other models should be determined as has been described for the '36 series. After this undesirable feature was called to the attention of the manufacturer in the late fall of 1936, the design was changed somewhat. Consequently the '37 series of instruments have heavier counterweights and heavier left links but not nearly as heavy as has been recommended here. Although they are undoubtedly better in this respect than the '36 gages, the '37 and later series have quite possibly given trouble also.

It is believed that the proposed changes will insure positive, dependable action of the gages, provided they are given reasonably good care. If the links and pinions are permitted to become gummy and dirty, a gage will not operate correctly even with the added weights. In this connection and contrary to the instructions accompanying the instruments, oil should not be put on the pinions and links or any other place from which it can spread to them. They should be cleaned in such a way as to remove any oily film that there might be, in order that dust and grit blown into the gage will not adhere to them.

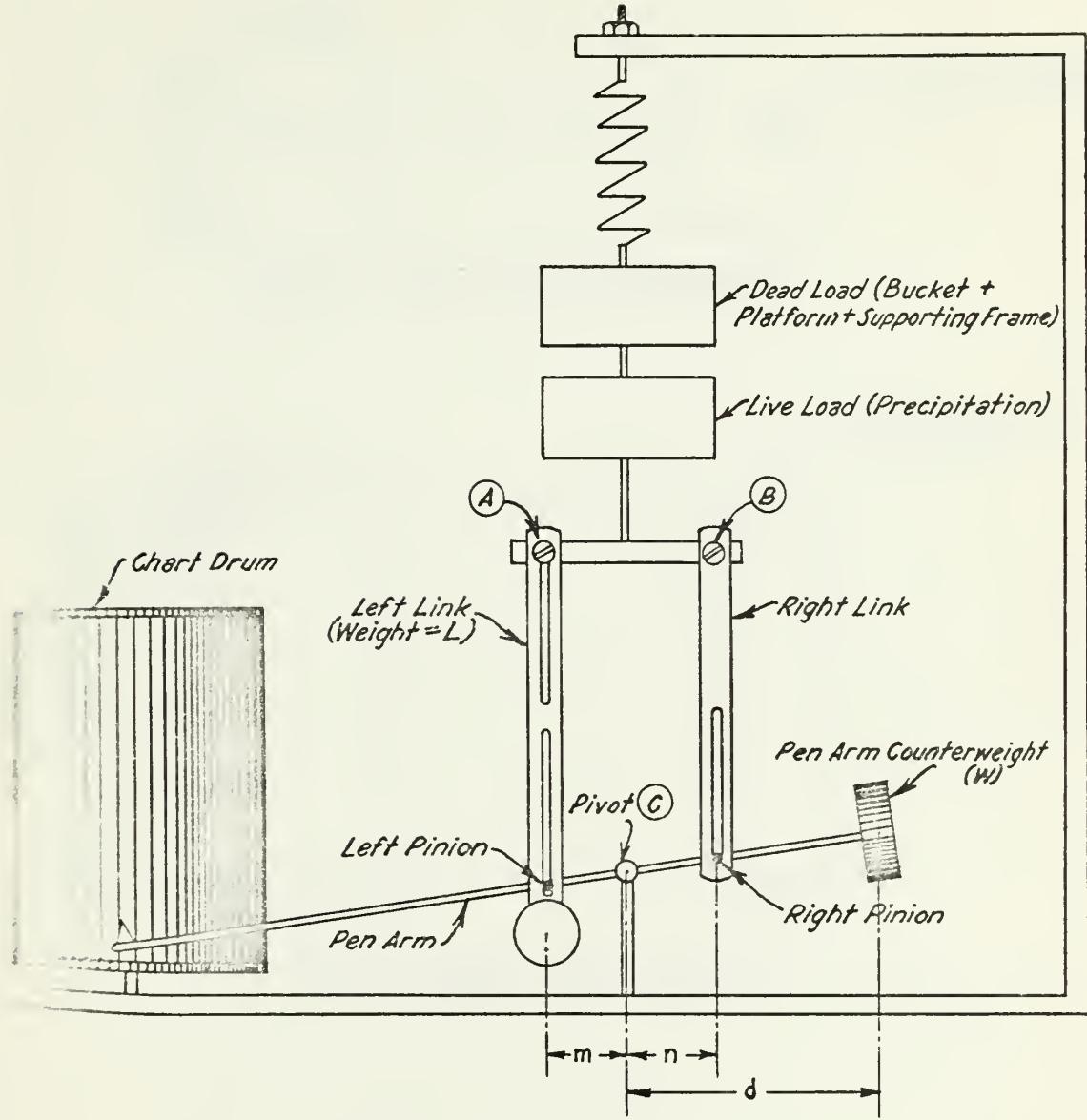
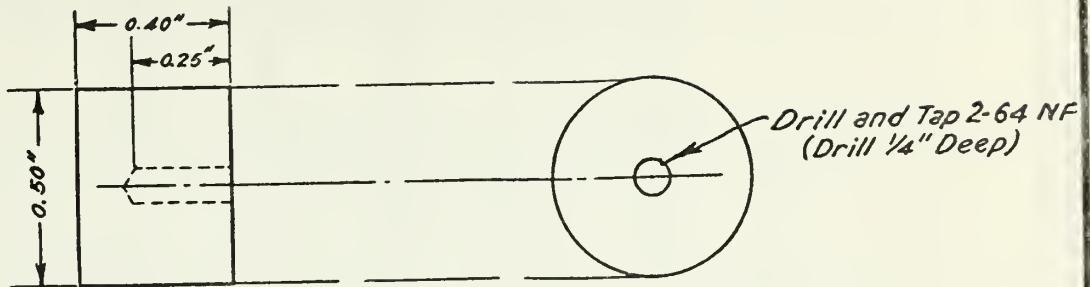
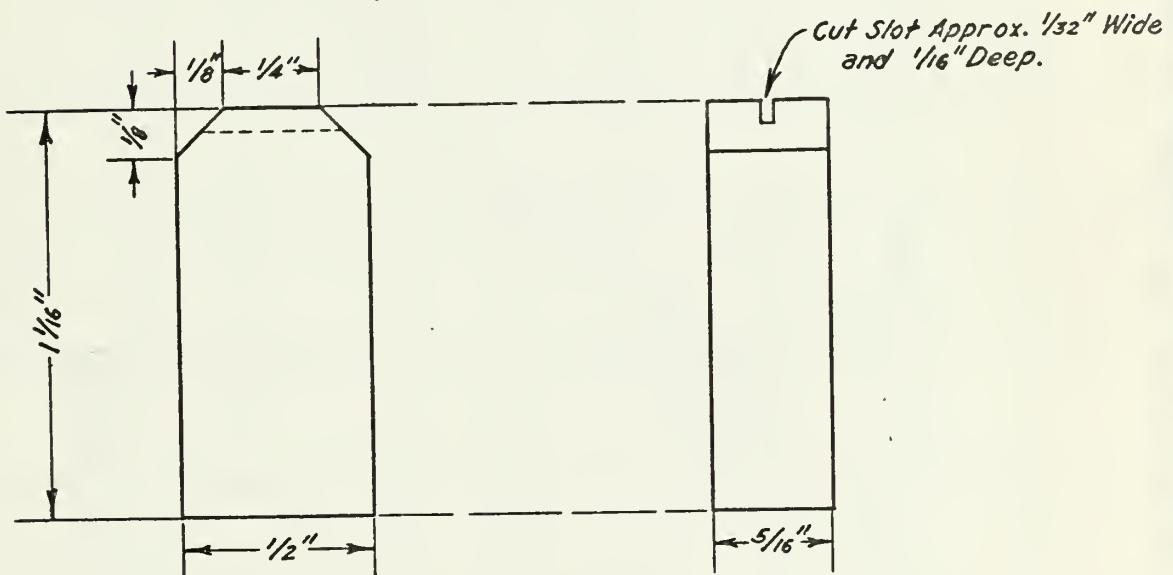


Figure 1.—Friez Recording Rain Gage.
Fergusson Type



Brass Pen Arm Counterweight



Brass Weight for Left Link

Figure 2.—Suggested Reversal Mechanism Weights
for the '36 Series of Fergusson Gages.

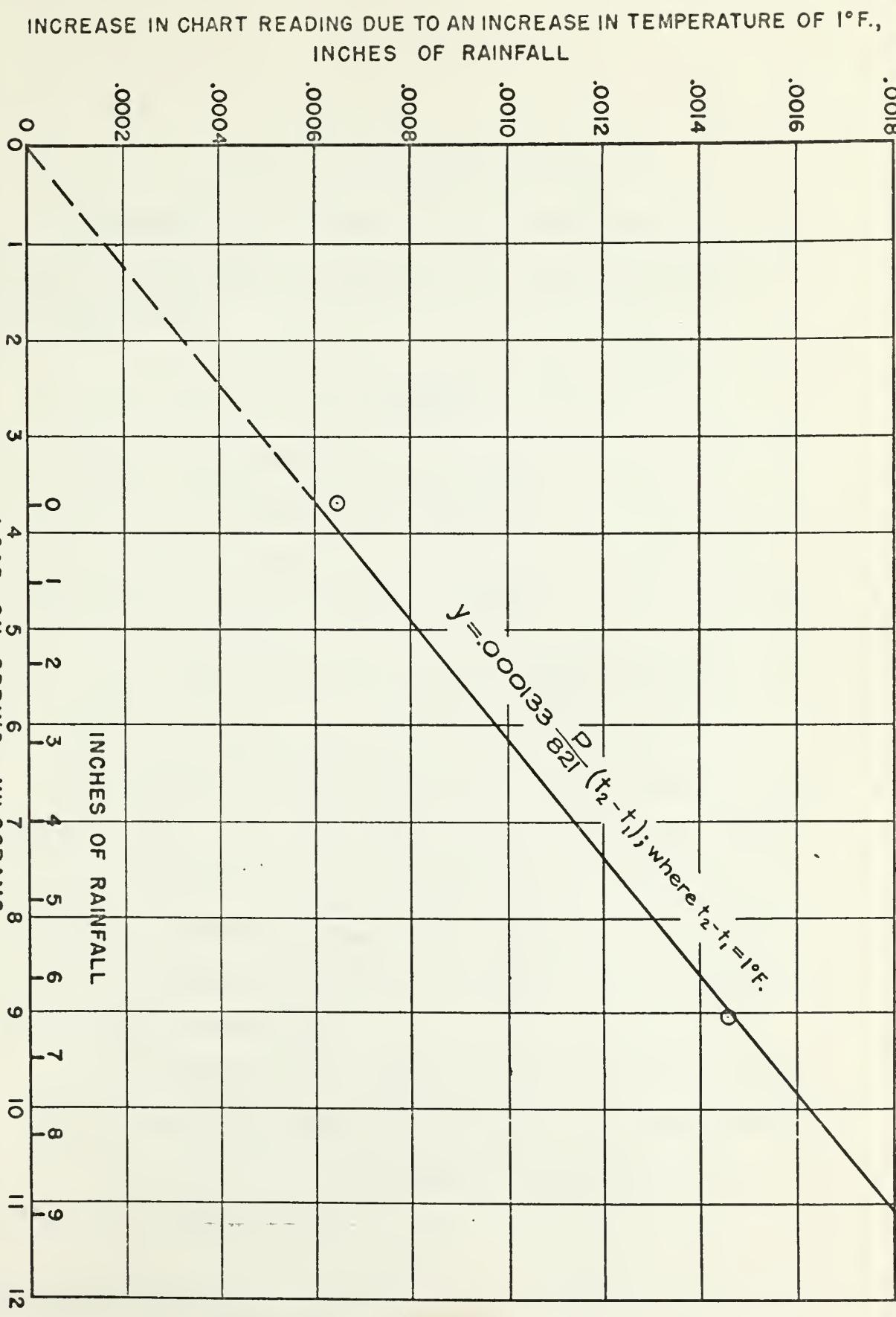


Figure 3.—Influence of Changes in Spring Characteristics Induced by Temperature Changes
(Gage No. 136-36)

EFFECTS OF TEMPERATURE ON THE SPRING

The deflection of a loaded spring is, among other things, a function of the modulus of rigidity of the spring material and of the length. Thus:

$$Y = \frac{8 P D^3 n}{E_s d^4}$$

where Y = deflection of the spring

P = load causing deflection

D = diameter of the coil

n = number of turns or coils

E_s = modulus of rigidity (or modulus of elasticity for shear)

d = diameter of the rod forming the coil

The modulus of rigidity, sometimes called the modulus of elasticity for shear, varies appreciably in most materials with temperature. The length also varies with temperature as expressed by the coefficient of thermal expansion. Using values from published material (1) for changes in these factors for spring steel, the change, y , in deflection is found to be

$y = .000133P(t_2 - t_1)$, where $(t_2 - t_1)$ is the change in temperature in degrees Fahrenheit. Or if expressed in inches of rainfall,

$y = .000133 \frac{P}{821}(t_2 - t_1)$ where P is the load on the spring, in grams.

(1) Keulegan & Houseman, Bureau of Standards R.P. No. 531.

Experiments on gage No. 136-36 confirm this relation, as shown by the plotted points in figure 3. From the figure it can be seen that at zero precipitation, because of the weight of the empty bucket, weighing platform and frame, a temperature change of 1° F causes a change in chart reading of 0.0006 inch of rainfall. In other words, an increase in temperature of 17° F between the time of setting the pen at zero and the time of observation will cause an indication of 0.01 inch of rainfall on the chart. At three inches of precipitation the load on the spring is greater and a temperature change of ten degrees will affect the recording by the amount of 0.01 inch of rainfall.

In the general case the resultant effect of the change in modulus of rigidity of the spring material is a little more difficult to comprehend. As an aid in doing so, let us take a particular example.

Assume that a gage is in perfect adjustment at a temperature of 90° F, with a reversal occurring at exactly the 3-inch line on the chart if a 3-inch precipitation load is placed in the bucket. Imagine further that the temperature has dropped 34° F to 56° F. Observation will show that at zero precipitation the pen will record at 0.02 inch of precipitation below the zero line. An adjustment is made at this temperature, by means of the knurled adjusting screw above and to the right of the spring, to bring the pen back to the zero line. Imagine now that the temperature drops again to 40° F, causing the pen to record approximately 0.01 inch of precipitation

below the zero line of the chart, and that thereafter exactly 3 inches of rain occurs and is caught by the gage. Because of the stiffening of the spring with a decrease in temperature of 50° F from that at which the reversal mechanism of the gage was originally adjusted the pen only moves a chart distance of 2.98 inches of precipitation for the 3-inch load. This 0.02 inch deficiency can be calculated by the formula. Adding this to the zero error of 0.01 inch gives a total error of 0.03 inch, with the pen recording at 2.97 inches.

The error can best be considered if divided into two parts: namely, that part arising from a temperature difference between the time of recording and the time at which the pen was set to zero, and that part occurring because of the difference between the temperatures of recording and adjustment of the reversal mechanism of the gage.

The first part, y_1 , may be thought of as a zero error which affects every chart reading by the same absolute amount, assuming no change in temperature during the time of recording. The sign of the error for the 3-6 inch traverse of the pen is opposite to that in the other two traverses. For gage No. 136-36 the load on the spring at zero precipitation was determined to be 3715 grams, the equivalent of 4.52 inches of precipitation. Then in this instance

$$y_1 = .000133(4.52)(t_r - t_o) = .0006 (t_r - t_o)$$

where: t_r = temperature of recording

t_o = temperature at the time of setting the pen on the zero line.

The second part, y_2 , is proportional to the amount of precipitation collected and is in the same direction regardless of the pen traverse. The magnitude and sign of this error is represented by the formula:

$$y_2 = .000133 I(t_r - t_a)$$

where: I = precipitation, inches

t_a = temperature at which the reversal mechanism of the gage was adjusted to give the correct pen traverse.

It can be seen that errors resulting from temperature changes are usually relatively small. They are, however, observable and the description has been included in the notes for the sake of completeness.

THE EFFECTS OF RELATIVE HUMIDITY CHANGES

A piece of paper changes its dimensions with changes in relative humidity and every instrument which makes a record of its movement on a piece of paper is subject to errors due to these changes. Some papers change in dimension more than others and most of them have a greater change in one direction than another. In general, there is a lesser change in the machine direction than in the across-machine direction. This has been attributed to the tendency of the fibers of the paper to orient themselves in the machine direction; and, as in wood, there is a lesser relative change in length with the grain than there is across the grain

with changes in moisture content. Paper, being thin, responds rather quickly to relative humidity changes.

Many persons have attempted to eliminate this difficulty but have come to no really satisfactory solution. By treating the paper with various materials, the rate of expansion and contraction has been reduced but the total ultimate amount not materially affected. In those instances where a material reduction has been made in the amount of change by certain manufacturing processes, there have been undesirable changes in other qualities. This is not to say that all papers are equally good, but the best is not good enough. Recent trials with charts that have been printed on paper backed with metal foil have shown that this type offers considerable promise of solving the relative humidity change problem.

It is not uncommon to have chart paper that changes dimension by 1 per cent in the across-machine direction with a relative humidity change from 50 to 95 per cent, and an increase in dimension at a much higher rate as the relative humidity approaches 100 per cent. The change in the other direction might be a sixth or a third of this amount. Whether to cut and print the chart to have the greater change in time or in precipitation is open to question; either way has its objectionable features. In the case of the Fergusson gage, the manufacturer has usually arranged to have the least expansion and contraction the long way of the chart, or around the drum. Then a change in chart width of 1 per cent is easily possible and it might be considerably more.

Changes in relative humidity with consequent changes in the chart dimensions affect the accuracy of recording the amount of precipitation in two ways. The obvious effect is to give a relative error in record equal to the relative change in chart dimension for the 0-3 inch traverse. Other things being equal, the reversal will occur above or below the 3-inch line on the chart depending upon whether the chart has contracted or expanded from its dimension at the time of calibration of the gage. The amounts of the errors just before and just after the reversal are equal in amount but opposite in sign. As precipitation increases to 6 inches both the actual error and the relative error in recording decrease to zero. For the 6-9 inch range the actual amount of error is the same as for the 0-3 inch range, the relative error being considerably less.

The other way in which changes in chart dimension affect the record is not so straightforward or predictable. The instruments are adjusted with the bottom of the chart snug against the drum flange and any movement of the chart from this position will affect the record by the amount of movement. It seems to be the case, more often than not, that when a chart is put on the drum correctly at a certain relative humidity, and thereafter the relative humidity first increases, expanding the chart, and then decreases, the chart does not return to its original position, but, instead, contracts about some point well above the bottom edge. As a result it has been found that the bottom edge will sometimes creep up the drum by an amount equivalent to several hundredths of an inch of precipitation. This amount has been noted to vary considerably at different points around the drum.

ADJUSTMENT OF THE REVERSAL MECHANISM

The design of these instruments is such that for correct recording there is a definite position for each moving part, relative to the position of the chart, for each amount of precipitation. This relation of moving part position to chart position is fixed at the time of adjustment of the reversal mechanism and if subsequently disturbed will cause the reversals to occur at wrong places. There are a number of things which may happen to alter this relation and when they do happen the gage is thrown out of adjustment, causing errors in recording.

Eccentric loading, which sometimes occurs when the platform is manually depressed, or may occur because of the instrument being out of level, causes excessive friction and binding. This will affect the recording but should not occur with reasonable care in handling and installation.

Two possibilities of maladjustment can be corrected simply by making an adjustment with the knurled adjusting screw above and to the right of the spring. One is a change in the weight of the bucket or weighing platform and the other is the zero error resulting from a change in temperature.

Some of the other possibilities which cannot be so easily taken care of are:

- (1) Bending of the pen arm in a vertical direction.
- (2) A change in the elevation of the drum flange.
- (3) A change in the width of the bottom margin of the chart.
- (4) A change in width of the chart.

- (5) Failure to have the bottom edge of the chart against the drum flange.
- (6) Changes in spring deflection due to temperature changes that cannot be taken care of by a zero adjustment.

For some of these items a zero adjustment by means of the knurled screw will cancel their effects over the first (0-3 inches) traverse, but they will become operative after the first reversal.

There follow step-by-step instructions for the adjustment of the reversal mechanism, if it should become necessary.

1. Set up the gage in the manner described in the instruction manual furnished by the manufacturer. Take particular care in placing the chart on the drum to make sure that the lower edge of the chart fits tightly against the bottom flange. Also be sure the bucket is dry, that there is no sticking or rubbing, and that the pen is adjusted to the exact zero of the chart. If the relative humidity is high (80 per cent or above) at the time of adjustment, so much the better.
2. Add water equivalent to 3 inches depth of rainfall (2463 grams for an 8-inch collector, apparent weight under usual conditions).
3. Raise left link so that it does not bear on left leverage pin (pinion) in such a way that the link's weight is still supported by the spring; or, raise the stop on this link temporarily. Adjust leverage of right link so that pen moves half way to the 3-inch mark on the chart. Move

- the right pinion to the left if the pen is below the mark and to the right if above.
- 4. Bring pen the remaining distance to the mark by means of the zero adjusting screw.
- 5. Check the zero reading. To do this, remove water from bucket and dry thoroughly. If not correct, adjust lever-age of right link, again bringing pen half the distance to zero and the remaining distance with the main adjusting screw. Check for 3-inch depth of water.
- 6. If the pen now reads correctly at the 3-inch mark with the left link raised, as described in paragraph 3, lower the link to its normal position and loosen the adjustable stop at the upper end of the lower slot. Move the stop up or down until it is in contact with the lever arm pin. When clamped in position this should cause a reversal at the 3-inch mark. Check the reversal by moving the bucket slowly up and down by hand..
- 7. Add water to make a total of 6 inches chart depth (4931 grams, equivalent to 6.006 inches for '36 series gages as received; or 4951 grams, equivalent to 6.03 inches if new reversal mechanism weights are used).
- 8. Raise the stop on the right link temporarily.
- 9. Adjust lever arm of left link to move the pen half the distance toward the 6-inch line.
- 10. Remove approximately half of the water, leaving 2463 grams in the bucket.

11. Readjust the stop on the left link to cause a reversal at the 3-inch mark.
12. Add water to make a total of 6 inches (4931 or 4951 grams, whichever is used) and set the adjustable stop on the right link to give a reversal at 6 inches on the chart.
13. Add water equivalent to 9 inches chart depth (7401 grams, equivalent to 9.014 inches for '36 series cages as received; or 7438 grams, equivalent to 9.06 inches, if new weights are used) and check the chart reading. There is no adjustment for errors in the last 3 inches of the range.

If new weights have been added to the reversal mechanism, the time of adjustment offers a good opportunity to check the values of the corrections for use in the 3-6 inch and 6-9 inch ranges. Using 821 grams of water for each inch of precipitation, add water in sufficient amounts to bring the pen near the center of the chart. The differences between the calculated and recorded amounts should be equal to the corrections derived by use of the formulae.

GENERAL COMMENTS

It should be realized that sizable errors in the recording of total catch can be obtained, that they may or may not be compensating, and that in many instances the error changes sign or, at least, changes abruptly in amount at the pen reversals. It appears, therefore, that it would be good practice to make an independent measurement of the total catch in the bucket at the end of the storm.

On the other hand, depending upon the purpose of obtaining the data, the possible errors may be considered negligible; and in all cases

it should be realized that the gage was designed primarily as an instrument for use in the determination of precipitation rates. Many of the possibilities for error do not enter, or enter to a small degree, in the determination of rates if the calculator avoids the use of two chart readings on opposite sides of a reversal or two time readings at opposite ends of the chart for any one rate determination.

The accuracy of rate determinations depends to a large extent upon the ability of the transcriber of the record in taking off the time and precipitation values for the intervals under consideration. From the standpoint of accuracy in determining time intervals a high chart speed is desirable.

To those who desire to make corrections to the precipitation amounts throughout the storm because of a difference between the total recorded and measured catch, Mr. H. L. Cook has made a good suggestion. Starting at the beginning of the rain and using the time at a reversal as the end of one interval and the beginning of another, add progressively the increments of rainfall used in the calculation of the rates. Include, in addition, any precipitation amounts necessary to correct for shifts in reversal mechanism weights occurring at the pen reversal points. Then all values for accumulated precipitation may be corrected in proportion to the deviation of the sum of the increments from the measured catch.

Mr. L. L. Harrold was instrumental in providing several gages for examination and aided in the calculation of the suggested new weights for the reversal mechanism.

